Front end of the RIA Driver Linac

R&D Category:
Driver Front End

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Office of Science
U.S. Department of Energy

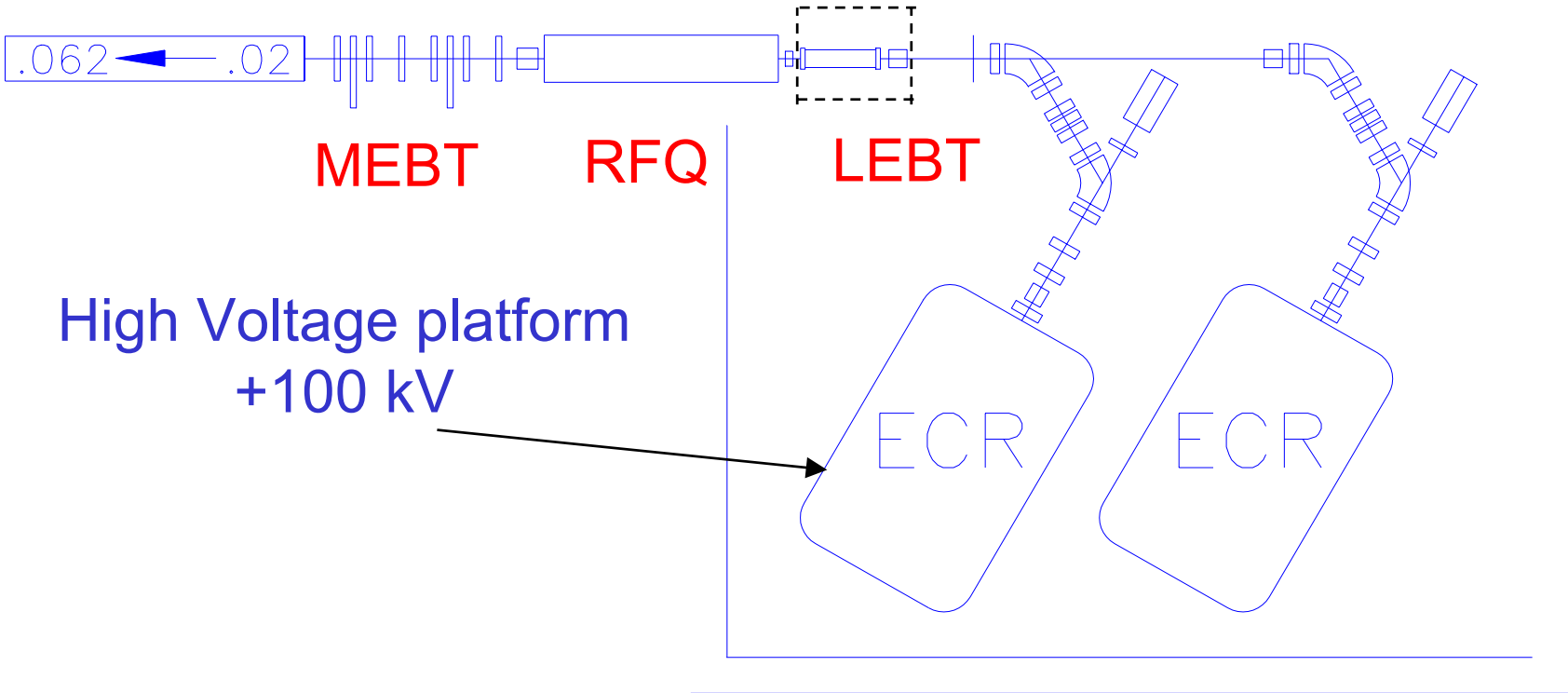
Pre-CDR design status of the front end

- Front end: form beams of one- or two-charge states with extremely low longitudinal emittance
- A design of the LEBT-RFQ-MEBT has been proposed.
- The following works related to the driver linac RFQ are completed:
  - Beam dynamics studies and vane modulation table.
  - Choice of resonant structure.
  - Thermal and structural analysis.
  - Test of the aluminum full-scale one-segment cold model.
  - Development of fabrication drawings of the one-segment full-power RFQ.
- A design of the prototype 2q-LEBT including ECR, achromatic bends, MHB and one-segment RFQ has been developed. For these tests a permanent magnet ECR is available immediately.

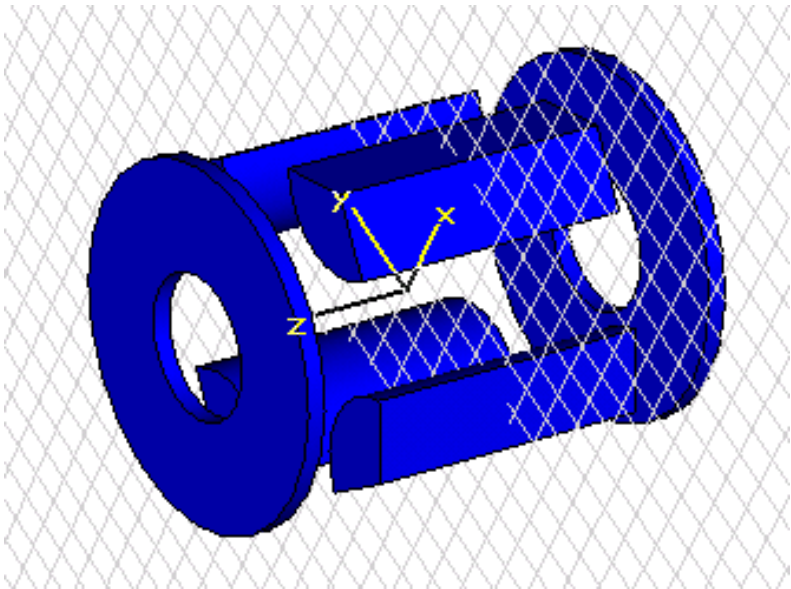
Layout of the RIA injector

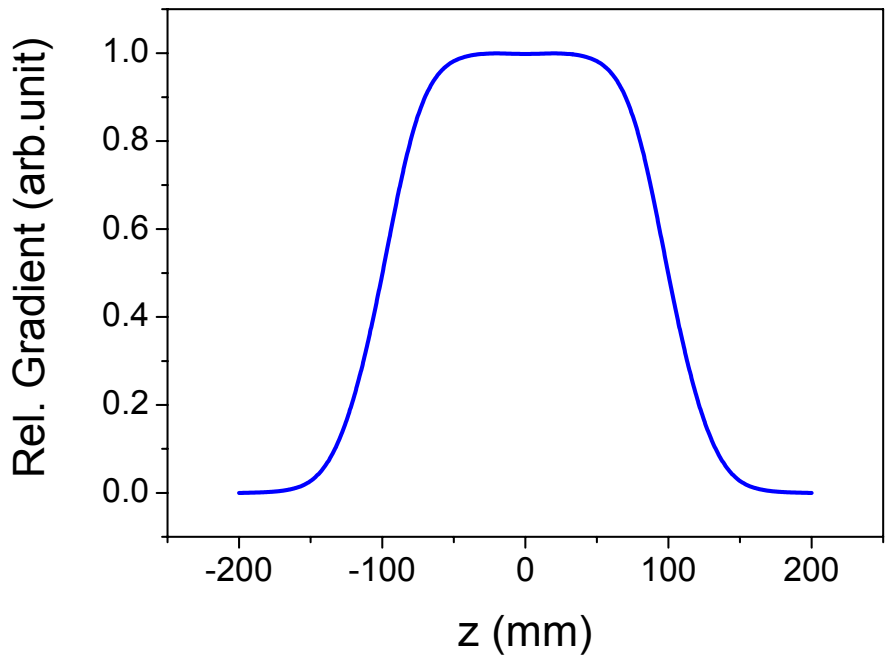
RFQ

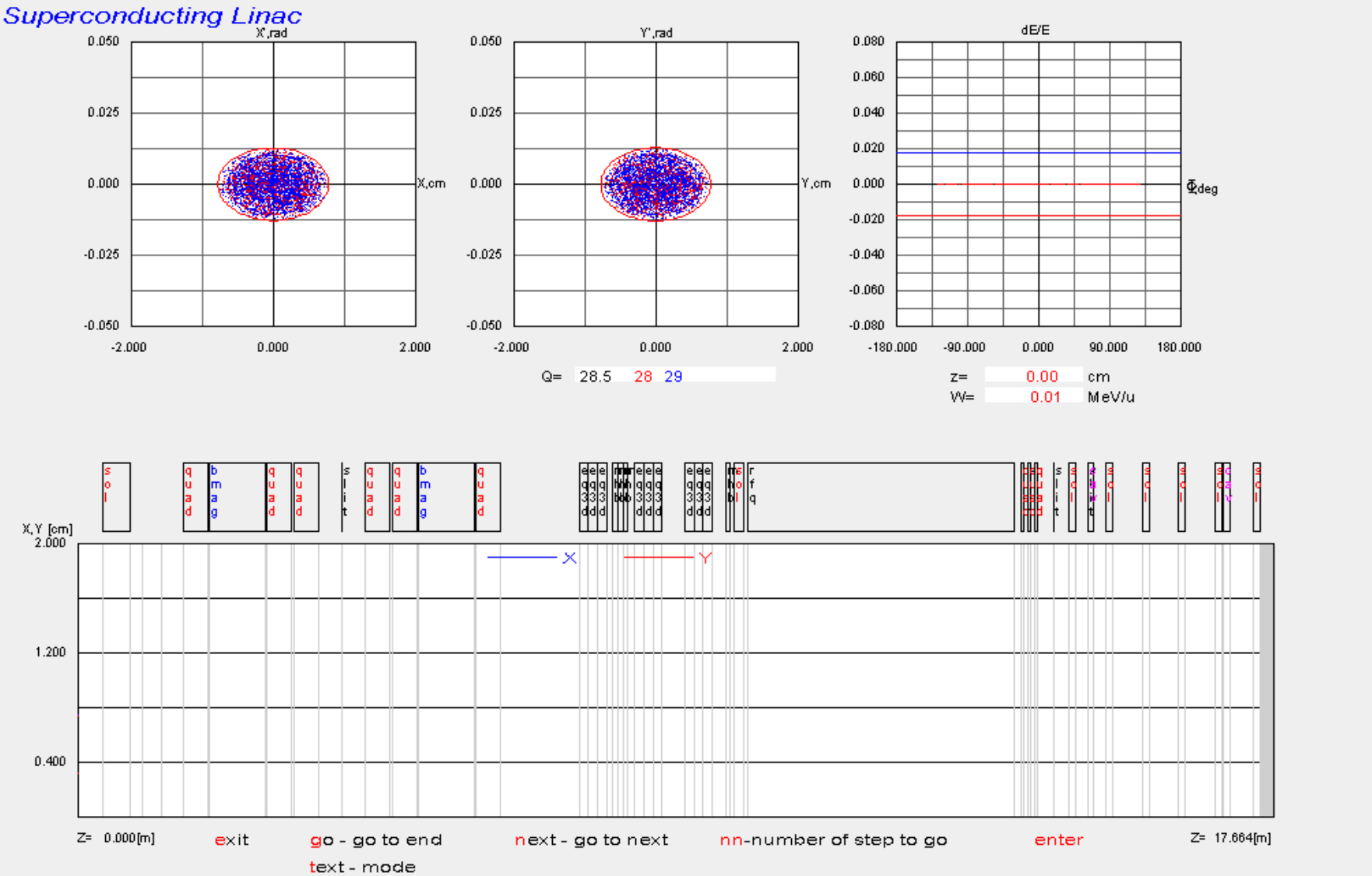
W_{out}=190 keV/u W_{in}=12 keV/u



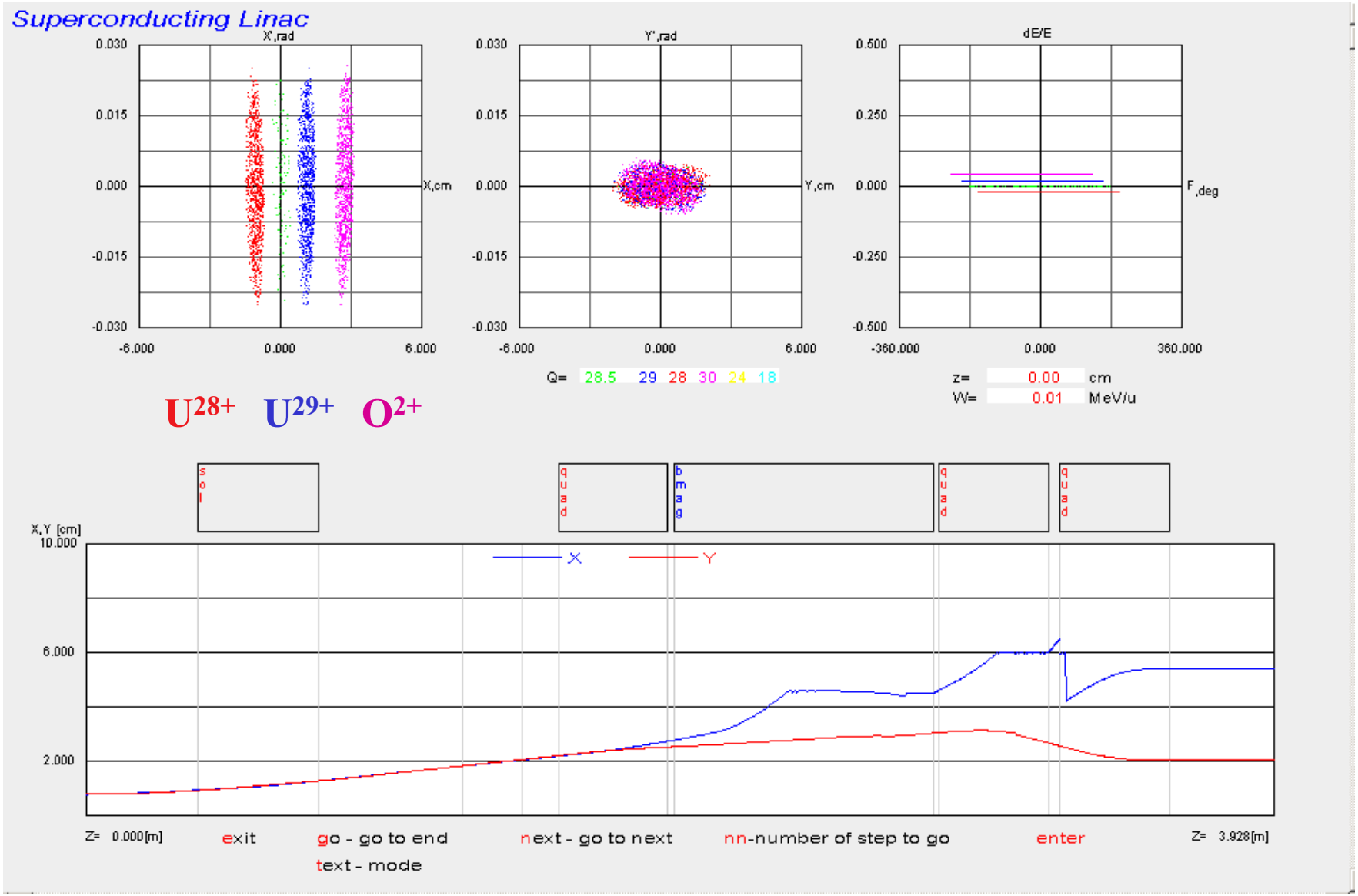
Focusing in the LEBT will be provided by electrostatic quadrupoles



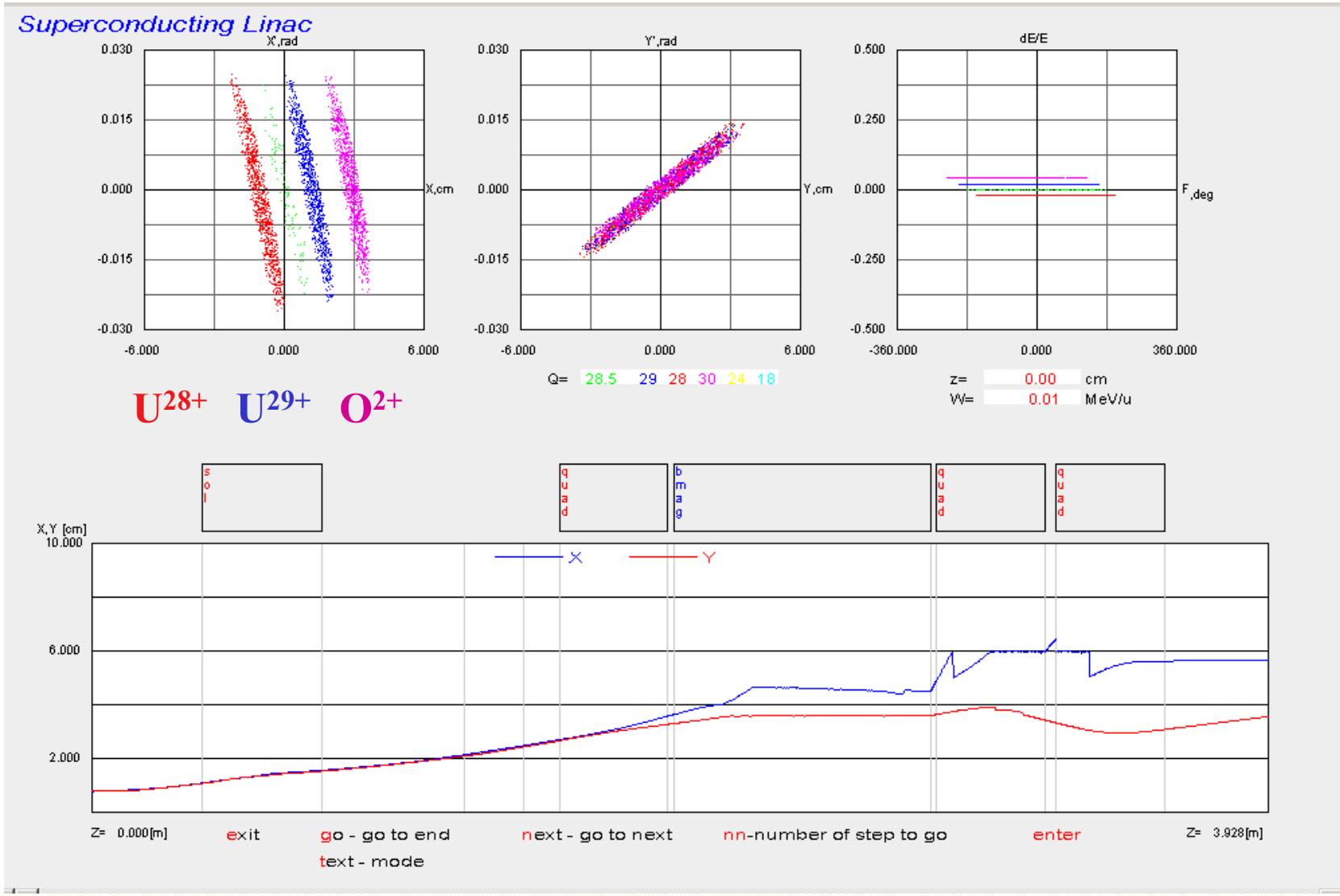


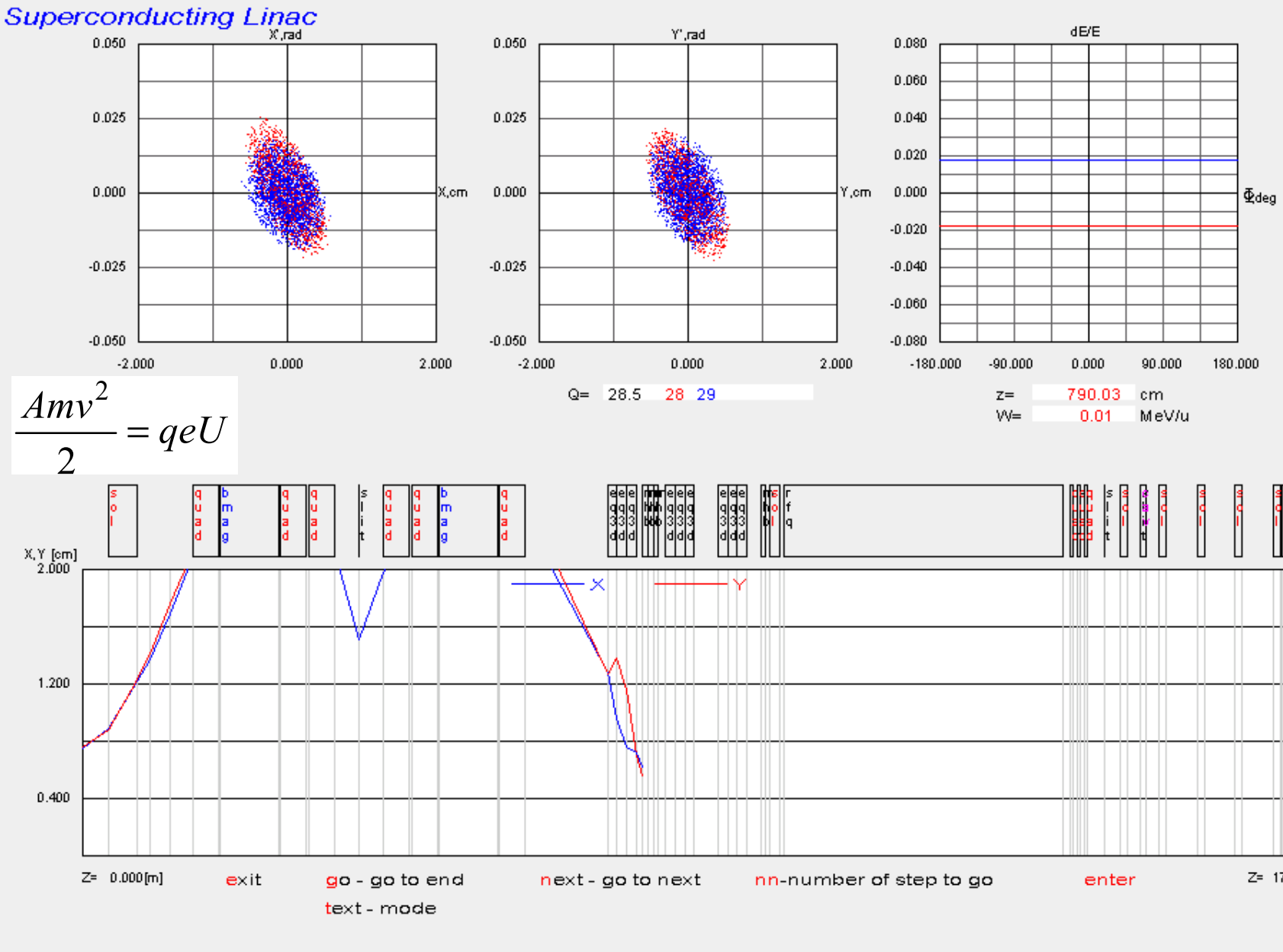

Superconducting Linac
X',rad
Y',rad
dE/E
X,cm
Y,cm
Φdeg
Q= 28.5 28 29
z= 0.00 cm
W= 0.01 MeV/u
X,Y [cm]
2.000
1.200
0.400
X
Y
Z= 0.000[m]
exit
go - go to end
text - mode
next - go to next
nn-number of step to go
enter
Z= 17.664[m]

No space charge

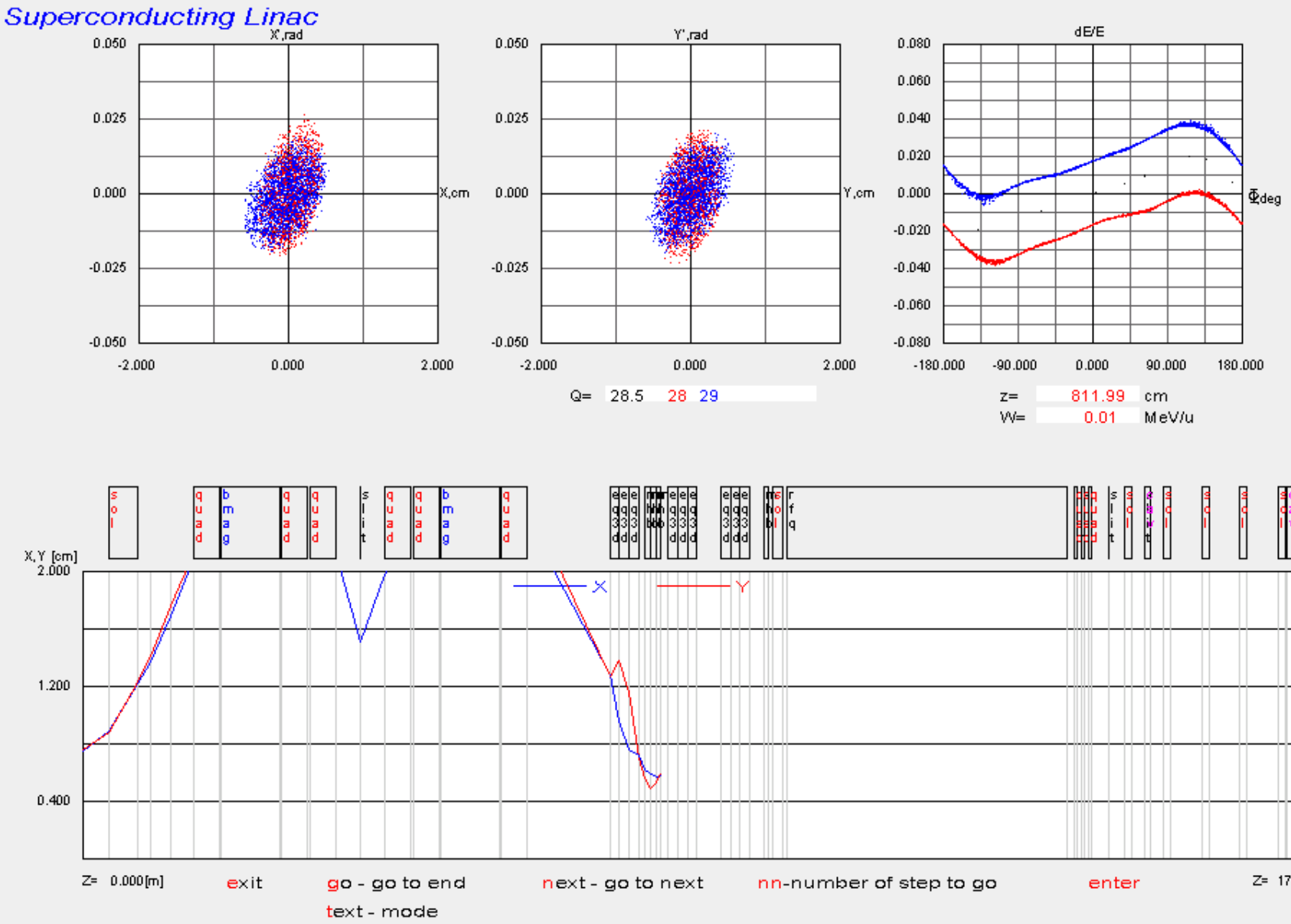


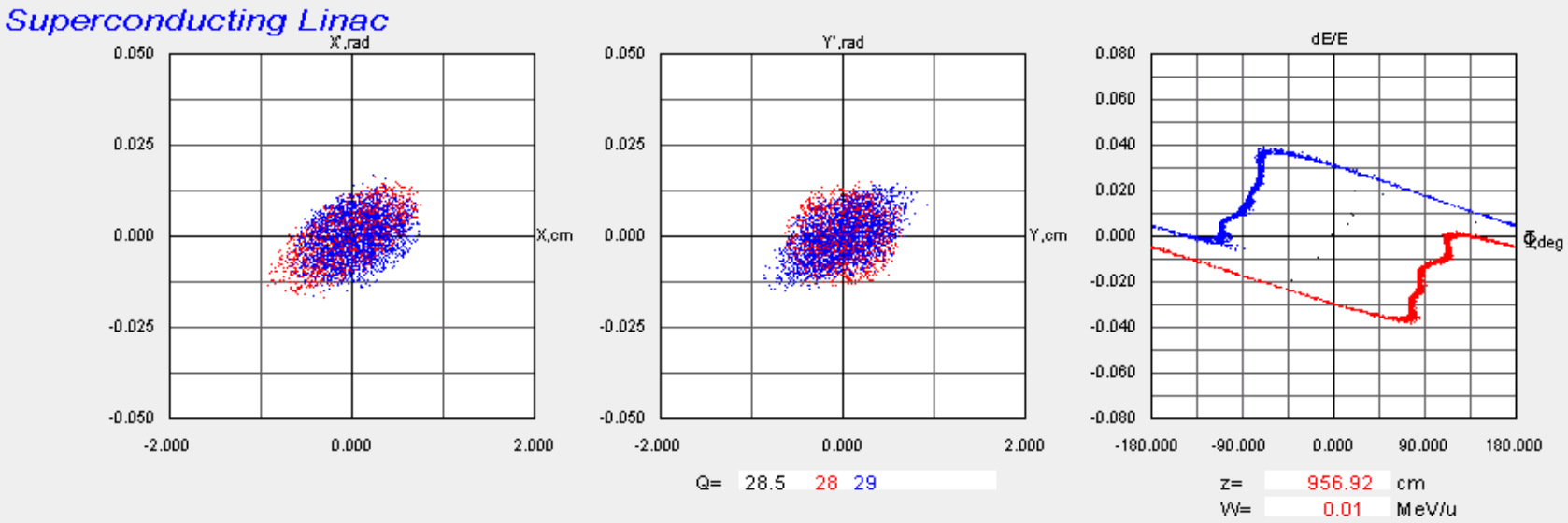
U^{28+} - 0.2 mA, U^{29+} - 0.2 mA, U^{24+} - 1.2 mA, U^{18+} - 0.8 mA, O^{2+} - 0.6 mA



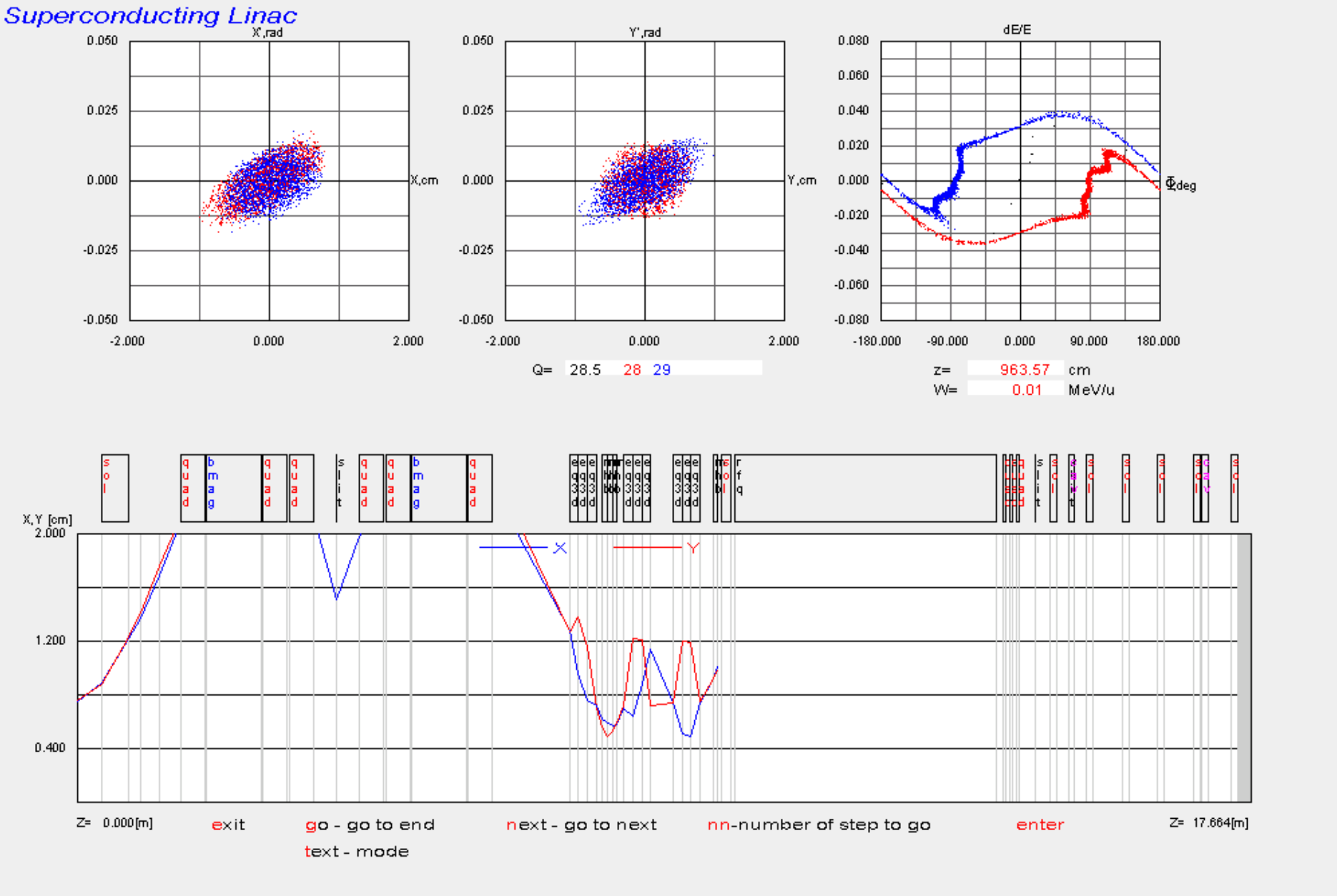


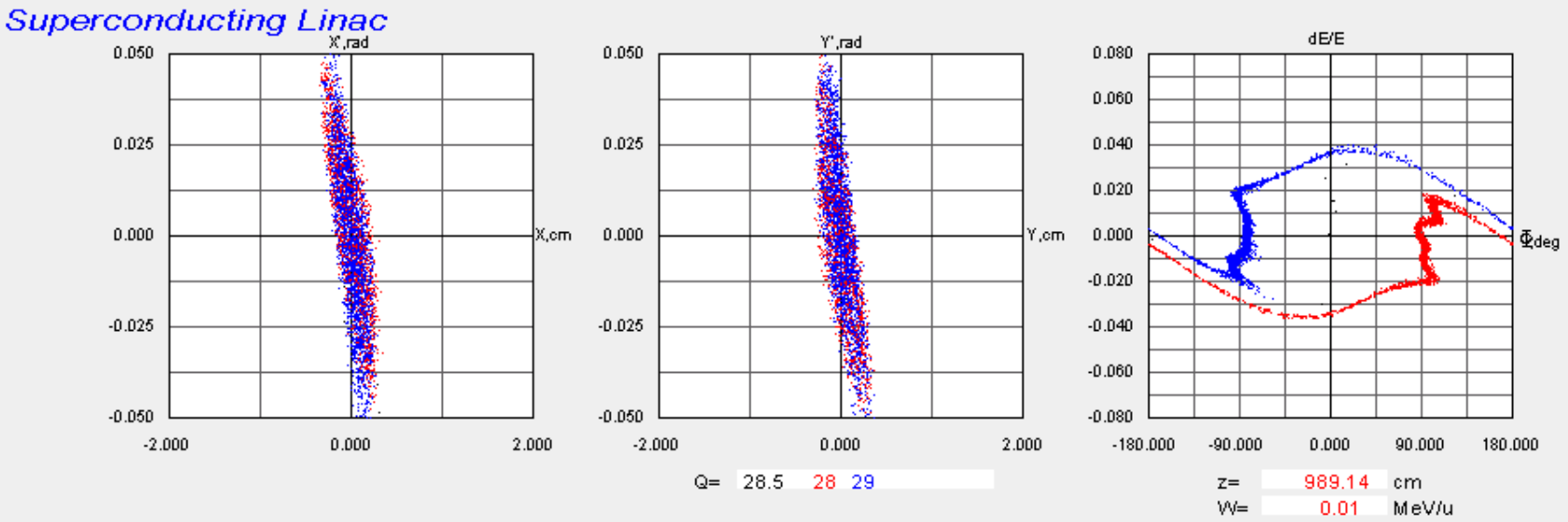
$$\frac{Amv^2}{2} = qeU$$

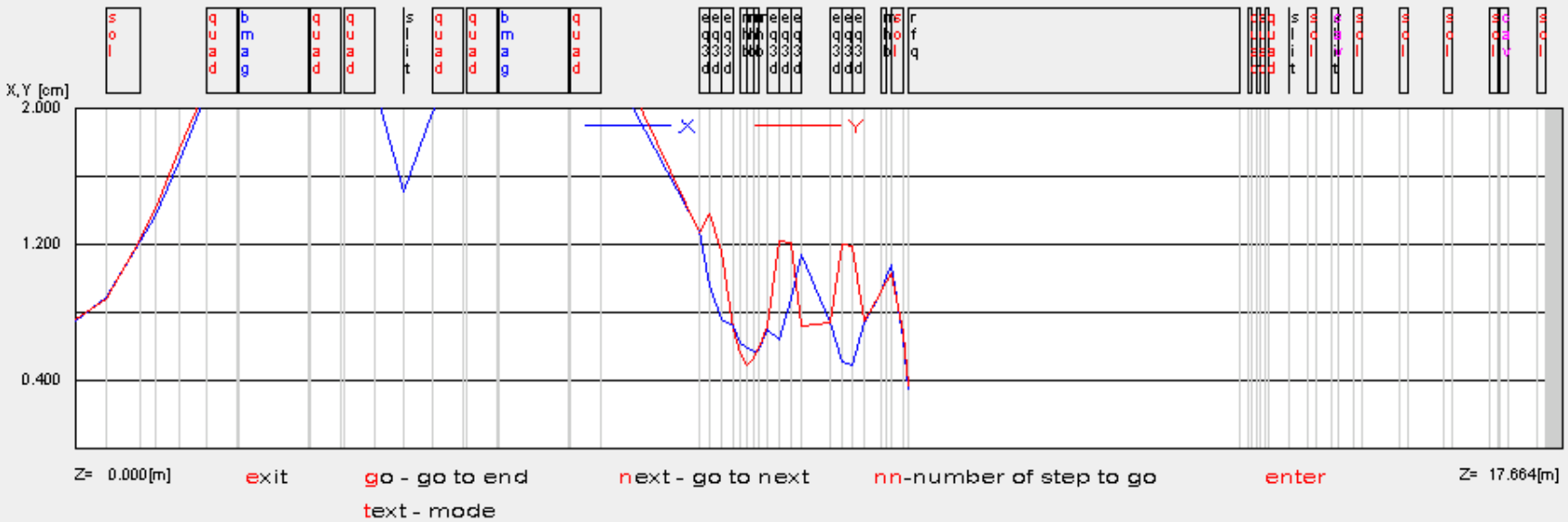

Superconducting Linac
X',rad
Y',rad
dE/E
X,cm
Y,cm
Φdeg
Q= 28.5 28 29
z= 811.99 cm
W= 0.01 MeV/u
X, Y [cm]
Z= 0.000[m]
exit
go - go to end
next - go to next
nn-number of step to go
enter
text - mode
Z= 17.664[m]

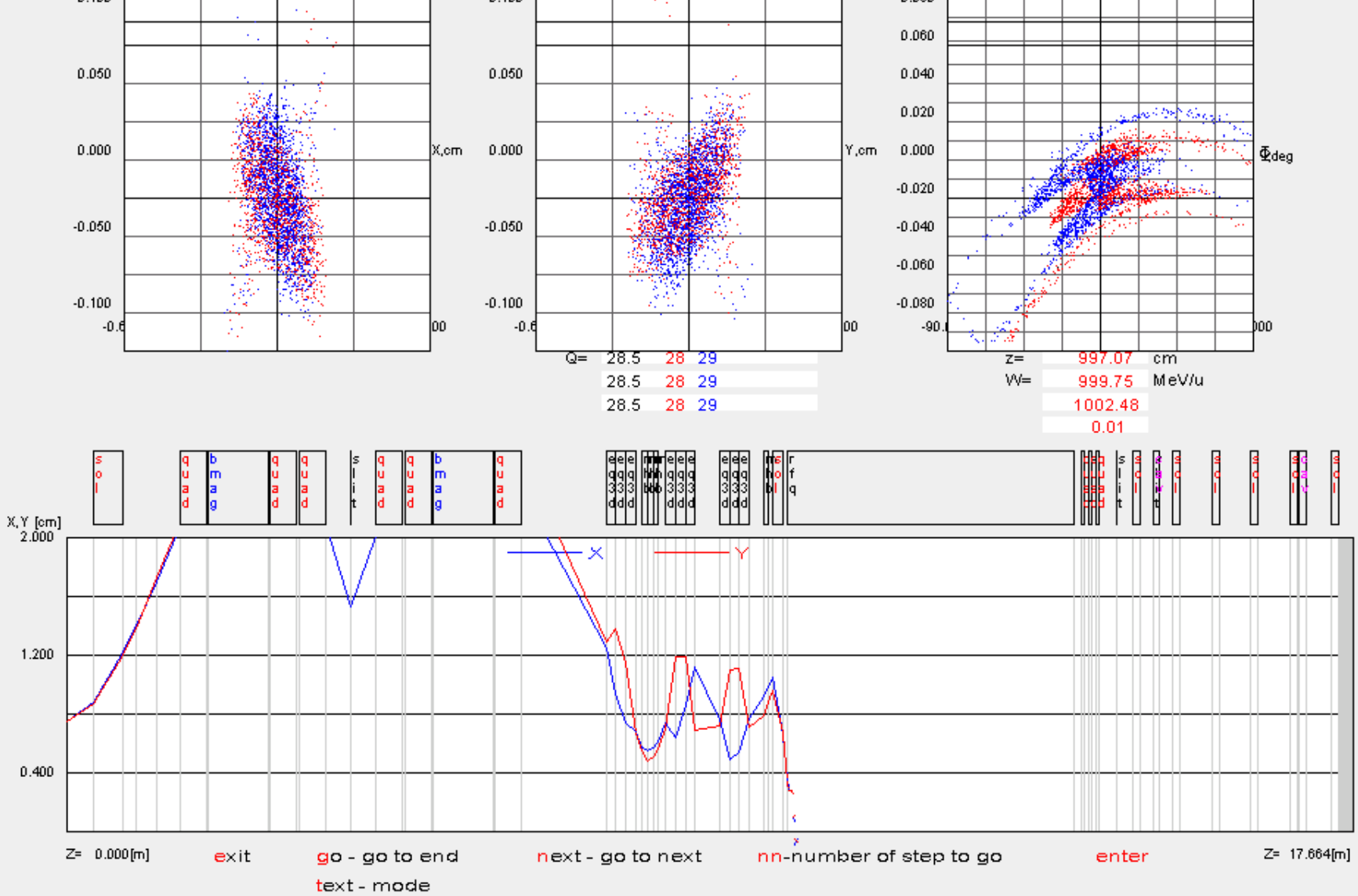


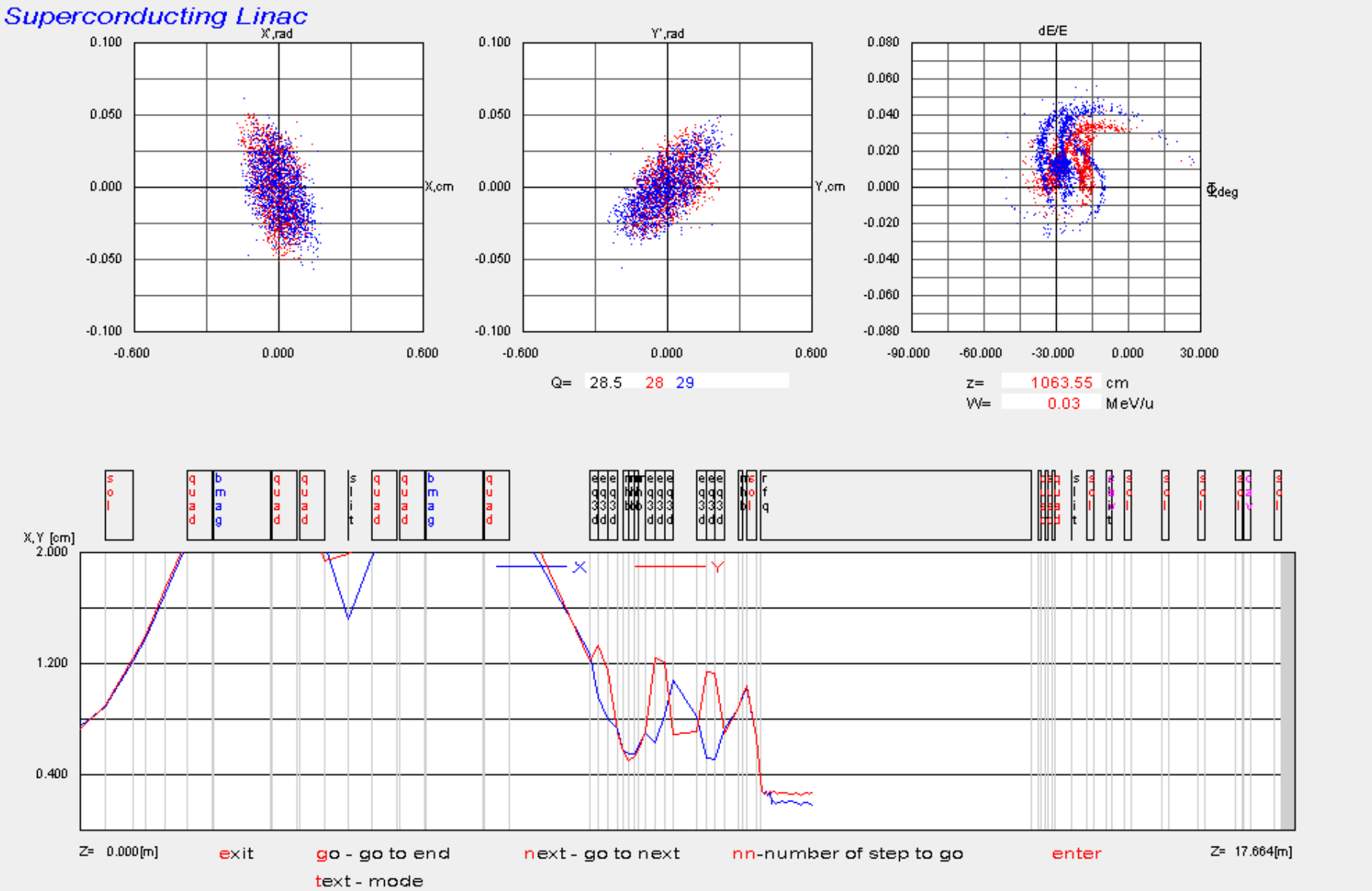
$$L = \frac{\lambda}{2}\sqrt{\frac{2eV}{Am_0c^2}}\frac{1}{\frac{1}{\sqrt{q_1}} - \frac{1}{\sqrt{q_2}}}$$

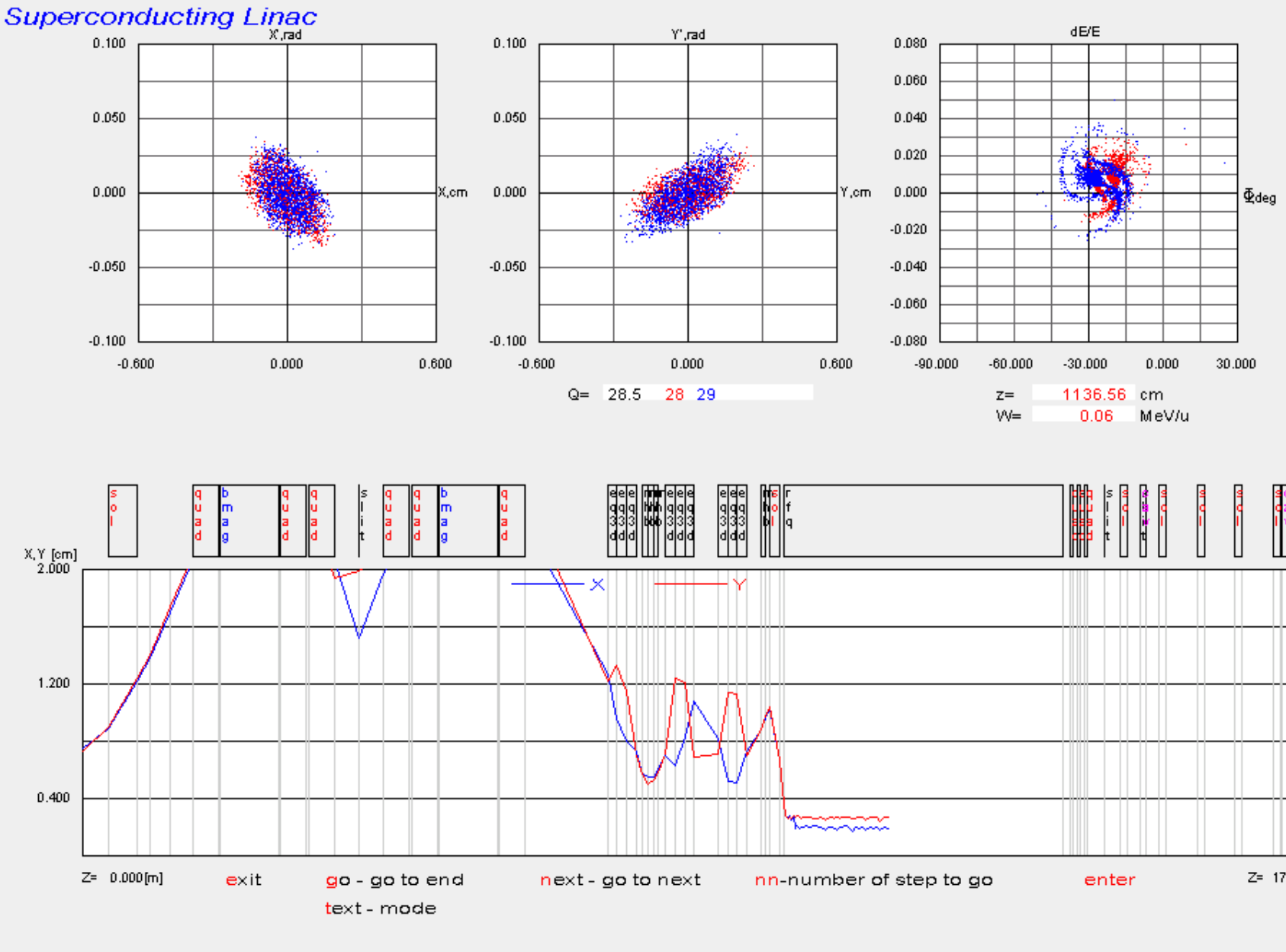

Superconducting Linac
X',rad
Y',rad
dE/E
X,cm
Y,cm
Φdeg
Q= 28.5 28 29
z= 963.57 cm
W= 0.01 MeV/u
X, Y [cm]
2.000
1.200
0.400
X
Y
Z= 0.000[m]
exit
go - go to end
next - go to next
nn-number of step to go
enter
text - mode
Z= 17.664[m]

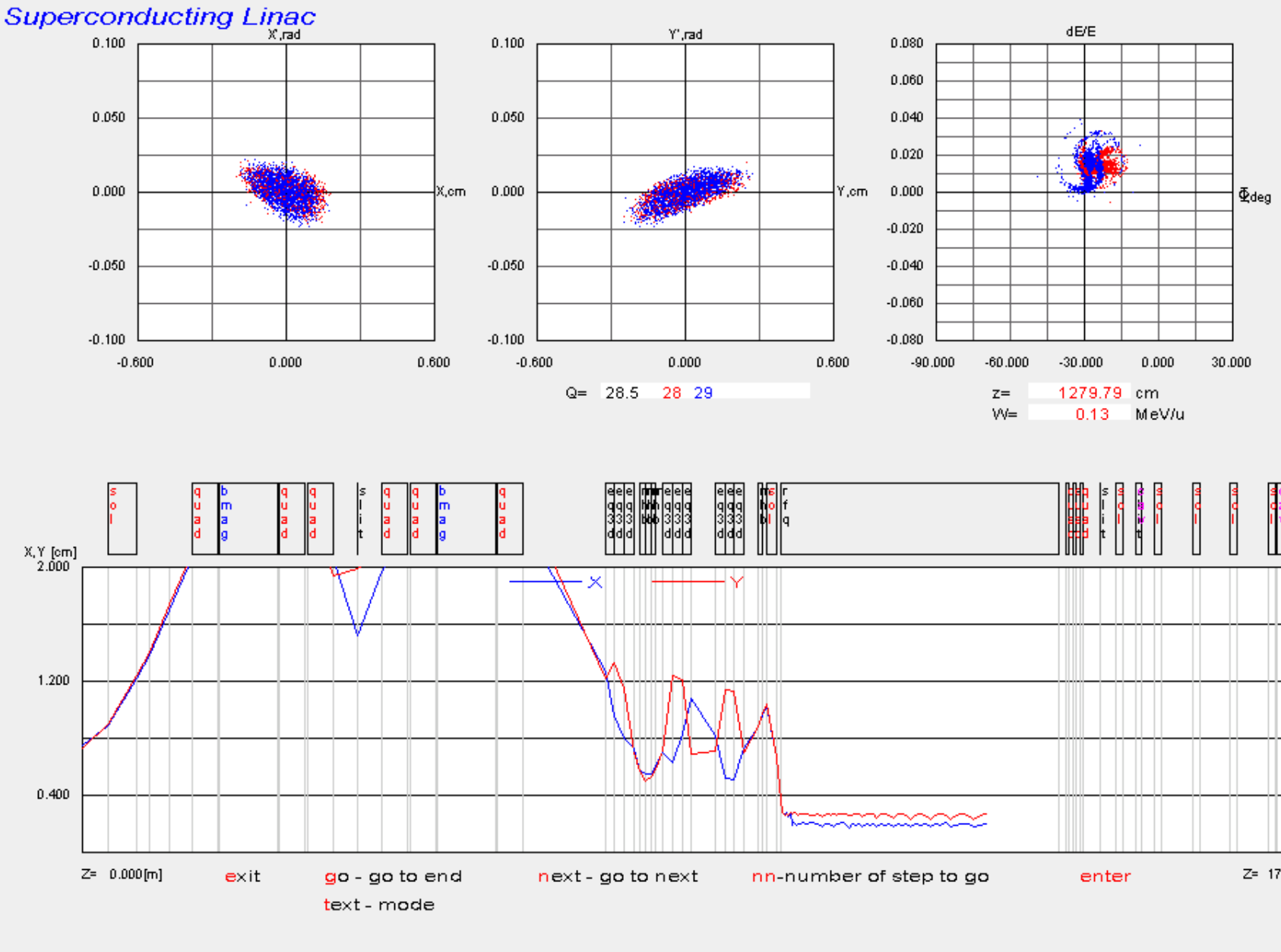

Superconducting Linac
X',rad
Y',rad
dE/E
X,cm
Y,cm
Φdeg
Q= 28.5 28 29
z= 989.14 cm
W= 0.01 MeV/u

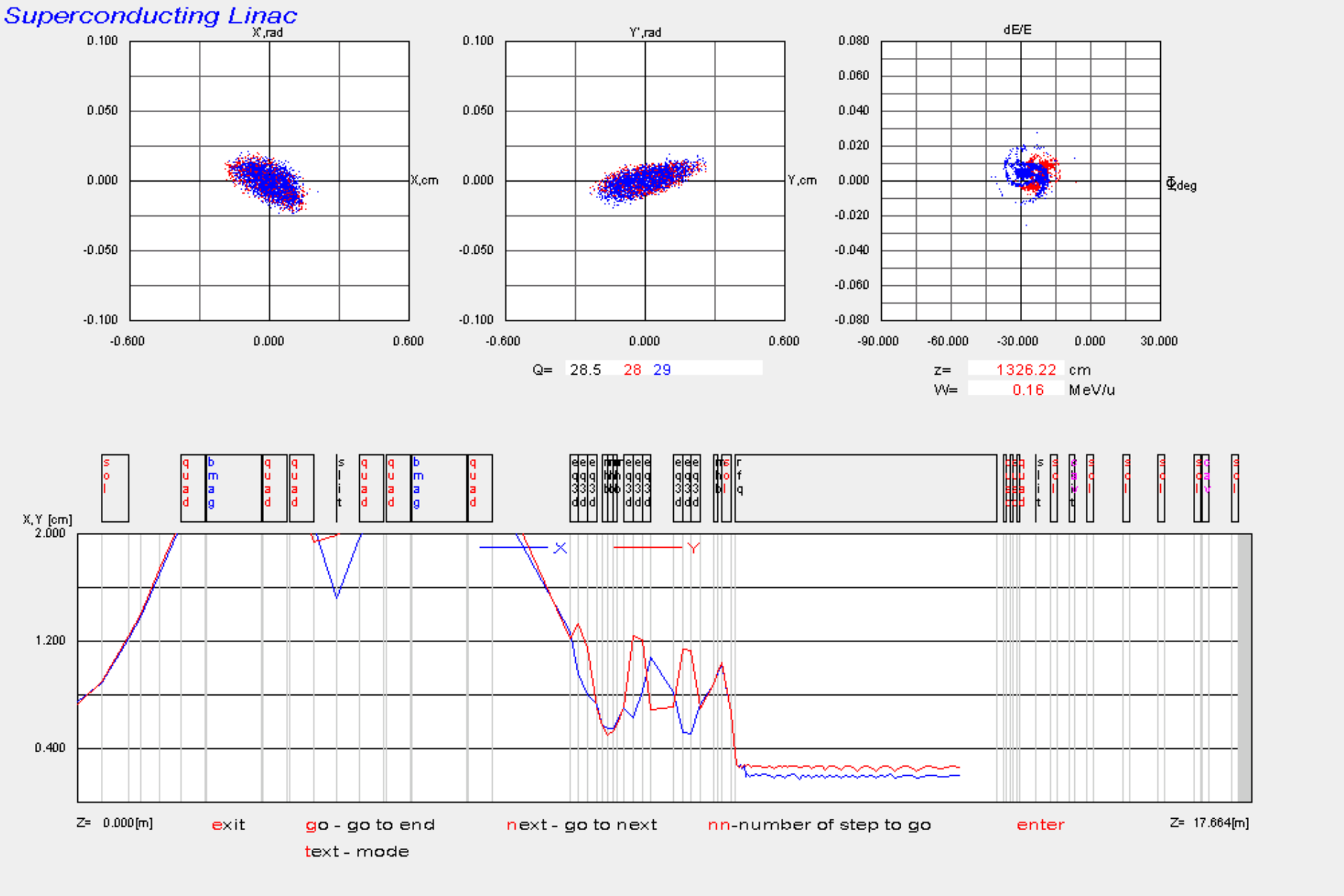

X, Y [cm]
2.000
1.200
0.400
X
Y
Z= 0.000[m]
exit
go - go to end
next - go to next
nn-number of step to go
enter
text - mode
Z= 17.664[m]

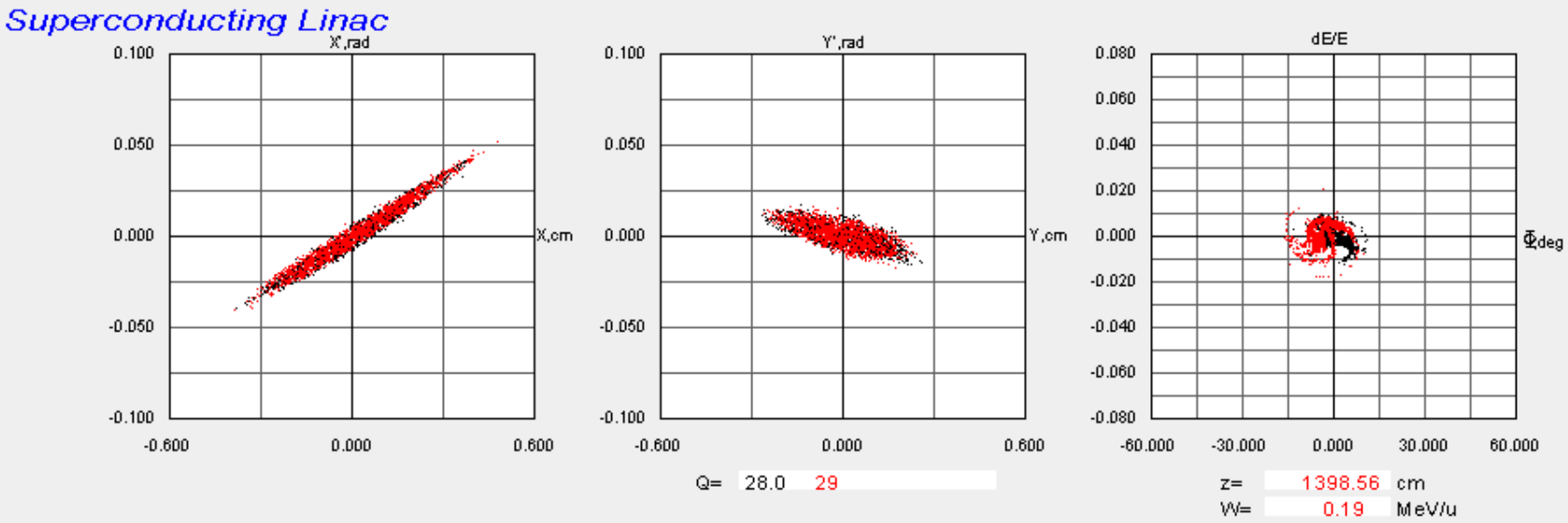

0.050
0.000
-0.050
-0.100
X,cm
Y,cm
0.060
0.040
0.020
-0.020
-0.040
-0.060
-0.080
Φdeg
Q= 28.5 28 29
28.5 28 29
28.5 28 29
z= 997.07 cm
W= 999.75 MeV/u
1002.48
0.01
X,Y [cm]
2.000
1.200
0.400
X
Y
Z= 0.000[m]
exit
go - go to end
text - mode
next - go to next
nn-number of step to go
enter
Z= 17.664[m]

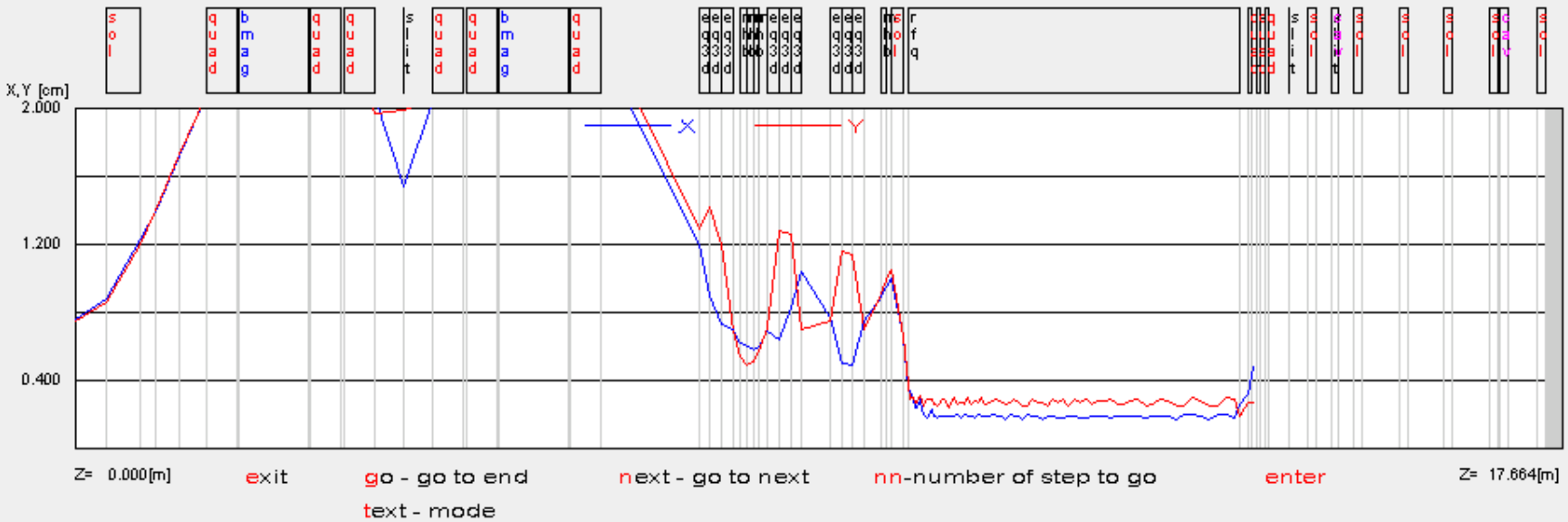

Superconducting Linac
X',rad
Y',rad
dE/E
X,cm
Y,cm
Φdeg
Q= 28.5 28 29
z= 1063.55 cm
W= 0.03 MeV/u
X, Y [cm]
X
Y
Z= 0.000[m]
exit
go - go to end
next - go to next
nn-number of step to go
enter
text - mode
Z= 17.664[m]

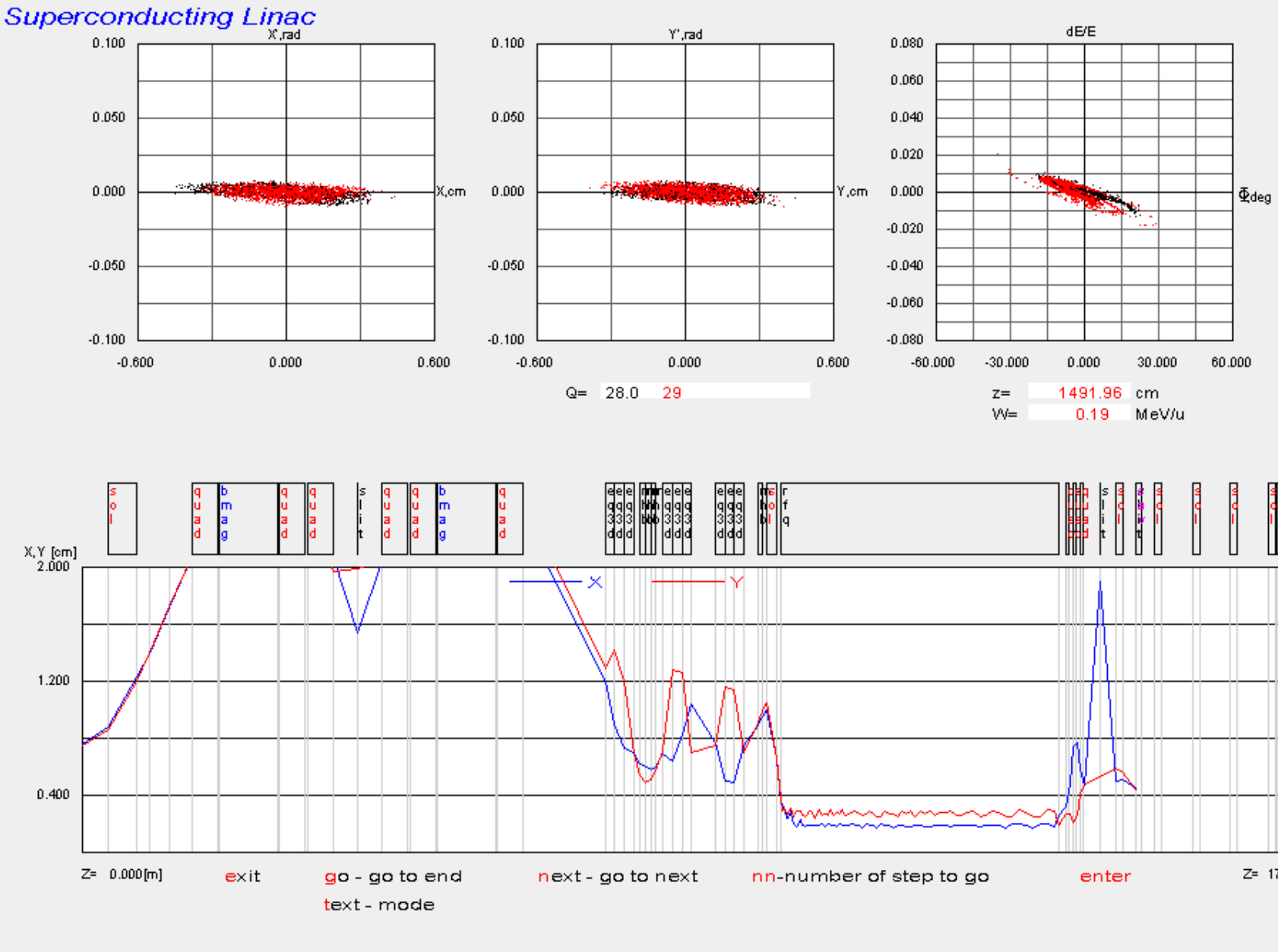

Superconducting Linac
X',rad
0.100
0.050
0.000
-0.050
-0.100
-0.600
0.000
0.600
X,cm
Y',rad
Y,cm
dE/E
0.080
0.060
0.040
0.020
-0.020
-0.040
-0.060
-0.080
-90.000
-60.000
-30.000
30.000
Φdeg
Q= 28.5 28 29
z= 1136.56 cm
W= 0.06 MeV/u
X, Y [cm]
2.000
1.200
0.400
X
Y
Z= 0.000[m]
exit
go - go to end
next - go to next
nn-number of step to go
enter
text - mode
Z= 17.664[m]

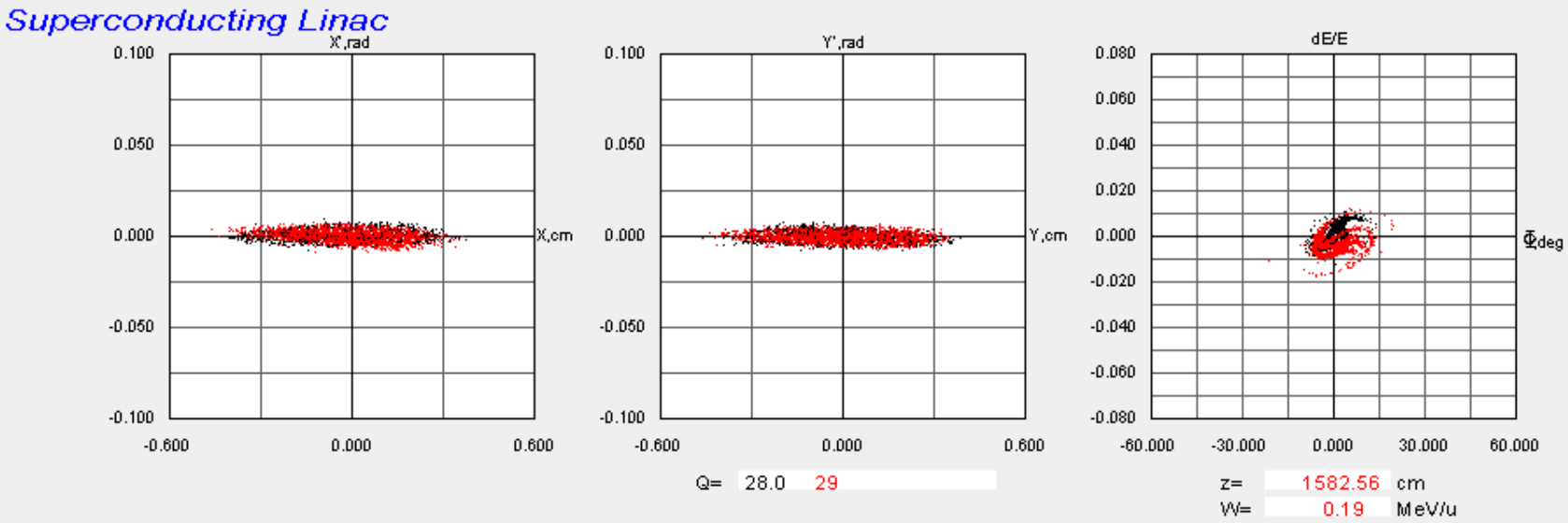

Superconducting Linac
X',rad
Y',rad
dE/E
X,cm
Y,cm
Φdeg
Q= 28.5 28 29
z= 1279.79 cm
W= 0.13 MeV/u
X, Y [cm]
X
Y
Z= 0.000[m]
exit
go - go to end
next - go to next
nn-number of step to go
enter
text - mode
Z= 17.664[m]

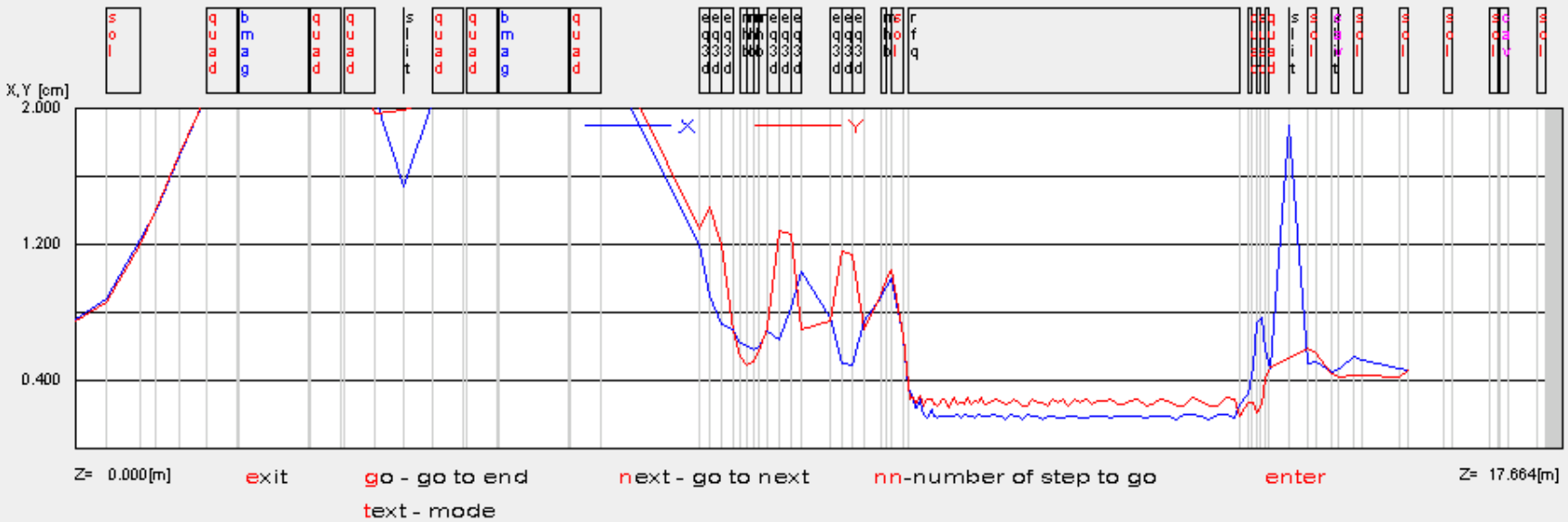

Superconducting Linac
X',rad
Y',rad
dE/E
X,cm
Y,cm
Φdeg
Q= 28.5 28 29
z= 1326.22 cm
W= 0.16 MeV/u
X, Y [cm]
X
Y
Z= 0.000[m]
exit
go - go to end
next - go to next
nn-number of step to go
enter
text - mode
Z= 17.664[m]

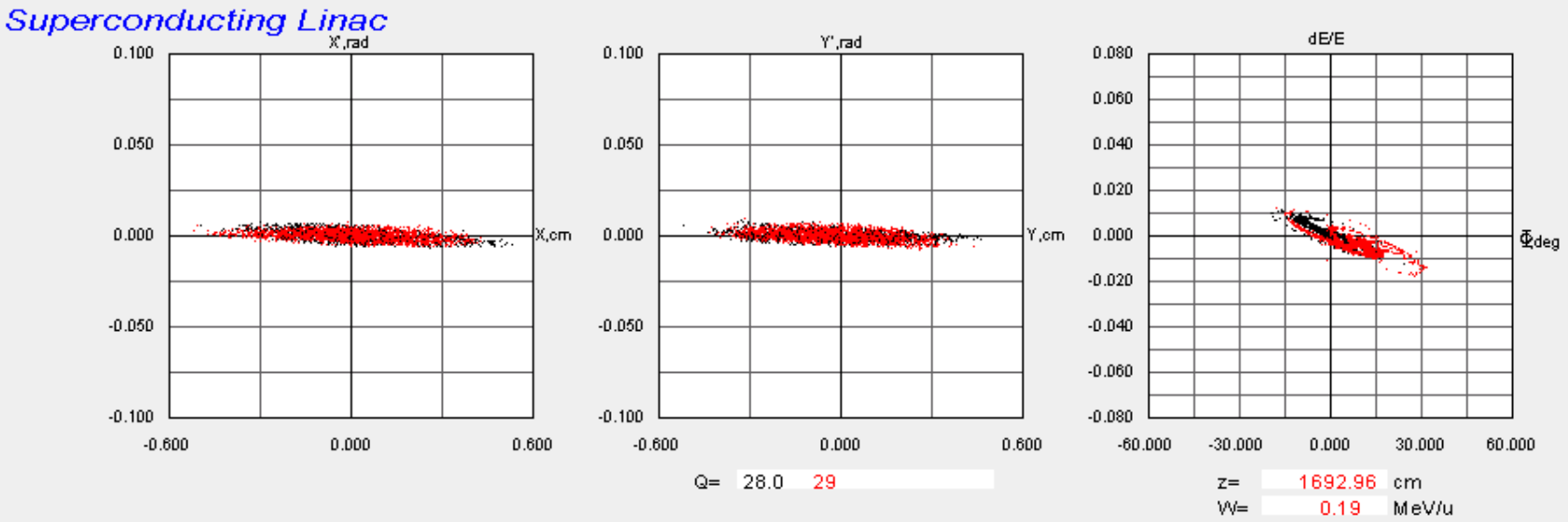

Superconducting Linac
X',rad
Y',rad
dE/E
X,cm
Y,cm
Φdeg
Q= 28.0 29
z= 1398.56 cm
W= 0.19 MeV/u

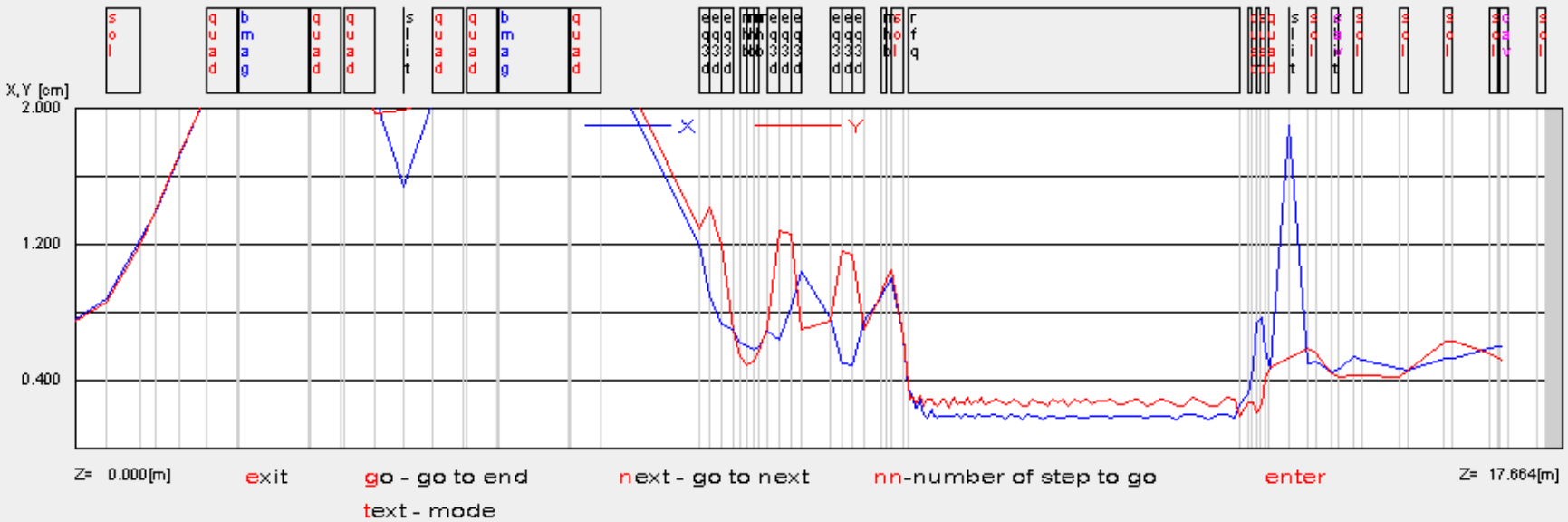

X, Y [cm]
2.000
1.200
0.400
X
Y
Z= 0.000[m]
exit
go - go to end
next - go to next
nn-number of step to go
enter
text - mode
Z= 17.664[m]

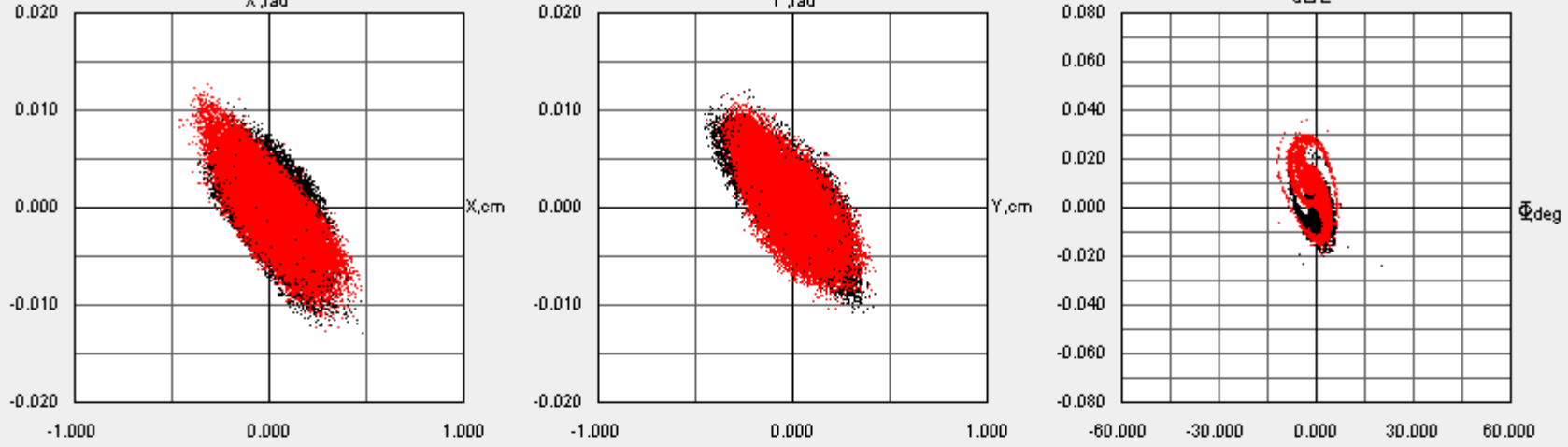

Superconducting Linac
X',rad
Y',rad
dE/E
X,cm
Y,cm
Φdeg
Q= 28.0 29
z= 1491.96 cm
W= 0.19 MeV/u
X, Y [cm]
X
Y
Z= 0.000[m]
exit
go - go to end
next - go to next
nn-number of step to go
enter
text - mode
Z= 17.664[m]


Superconducting Linac
X',rad
Y',rad
dE/E
X,cm
Y,cm
Φdeg
Q= 28.0 29
z= 1582.56 cm
W= 0.19 MeV/u


X, Y [cm]
2.000
1.200
0.400
X
Y
Z= 0.000[m]
exit
go - go to end
next - go to next
nn-number of step to go
enter
Z= 17.664[m]
text - mode


Superconducting Linac
X',rad
Y',rad
dE/E
X,cm
Y,cm
Φdeg
Q= 28.0 29
z= 1692.96 cm
W= 0.19 MeV/u

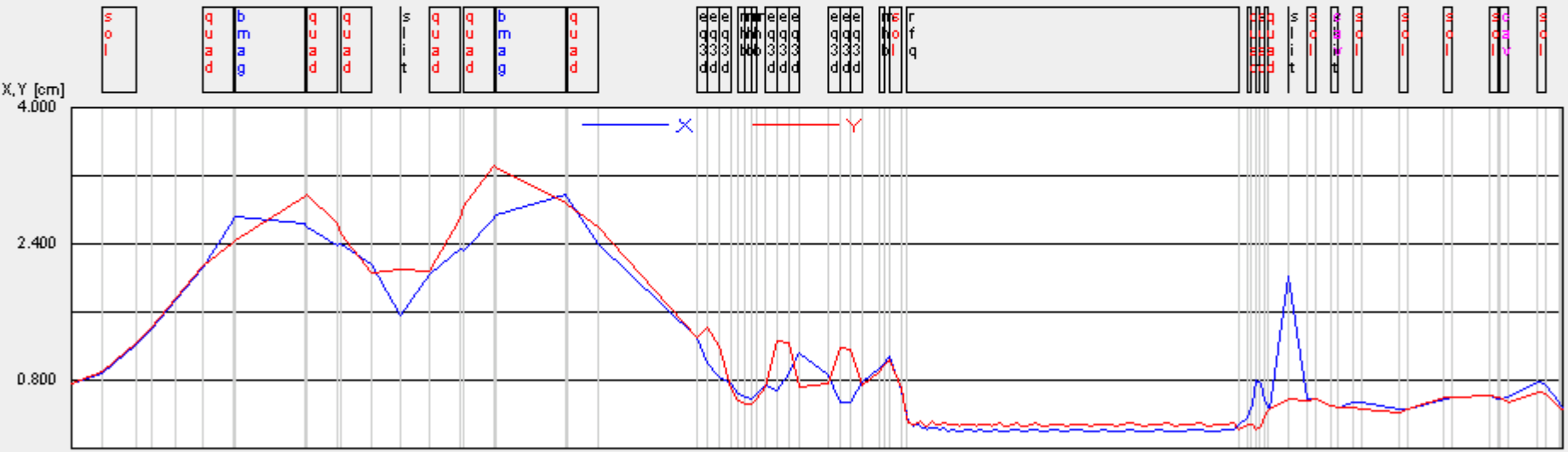

X, Y [cm]
2.000
1.200
0.400
X
Y
Z= 0.000[m]
exit
go - go to end
next - go to next
nn-number of step to go
enter
Z= 17.664[m]
text - mode



Q= 28.0 29

z= 1767.16 cm

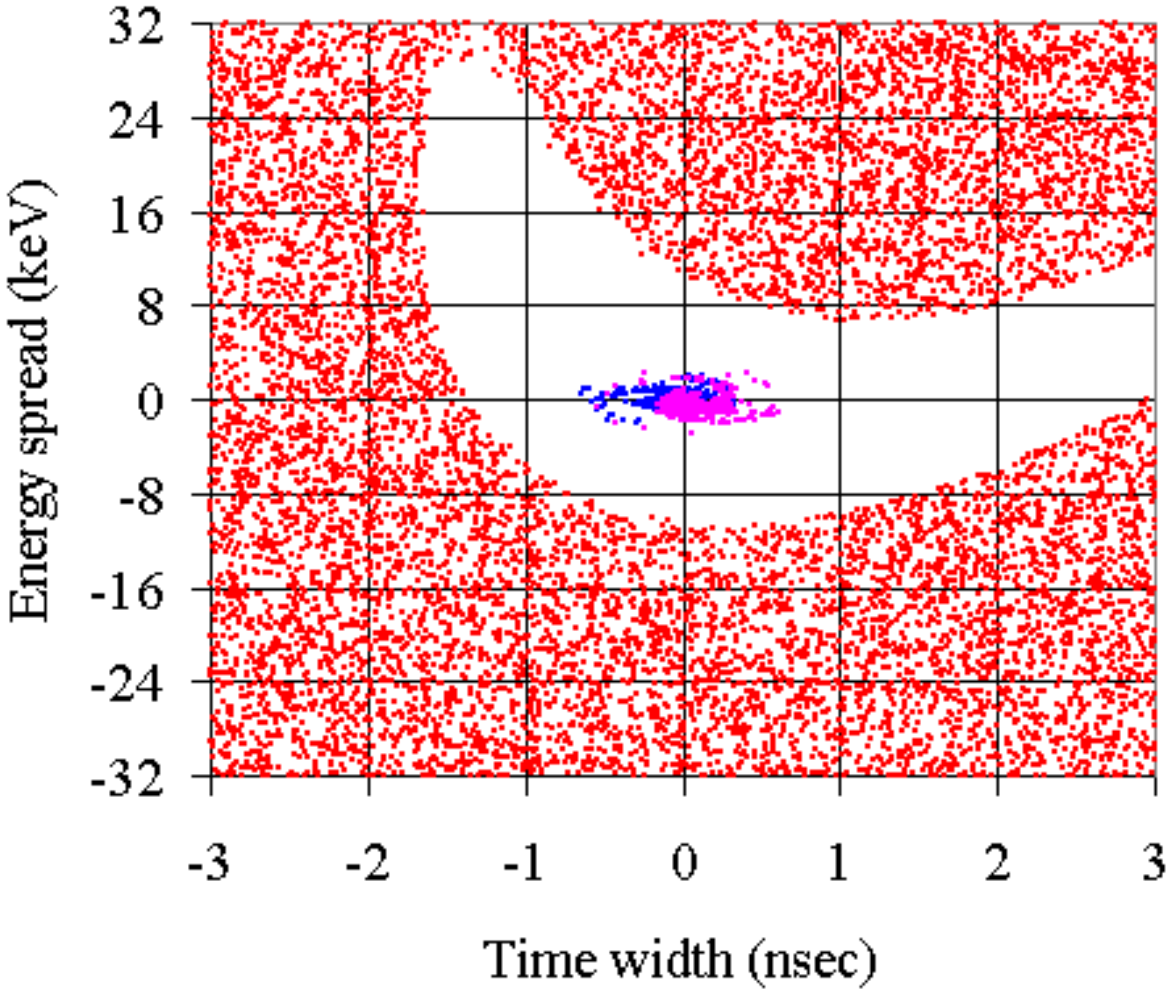
W= 0.19 MeV/u



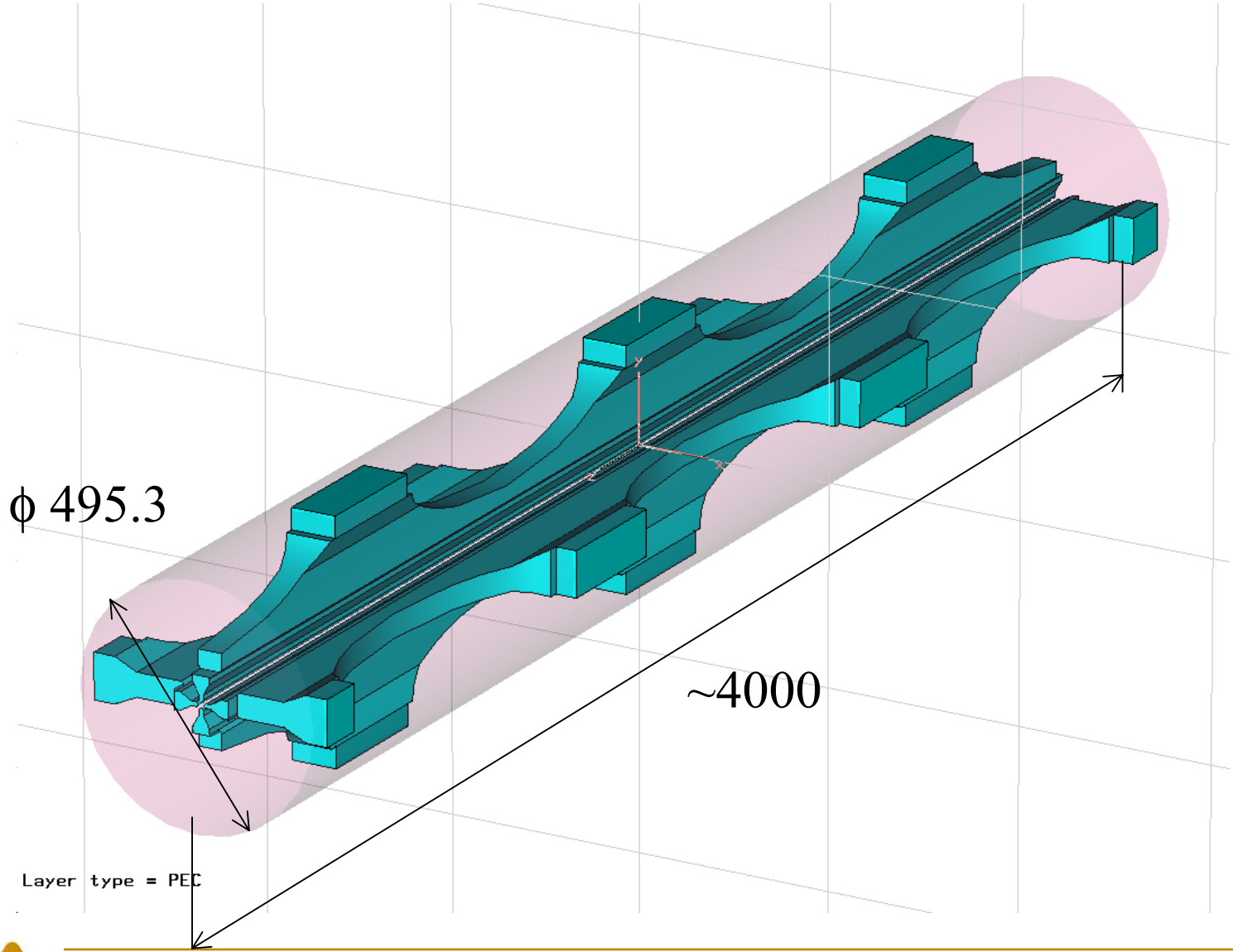
Z= 0.000[m] exit go - go to end next - go to next nn-number of step to go enter Z= 17.664[m]

text - mode

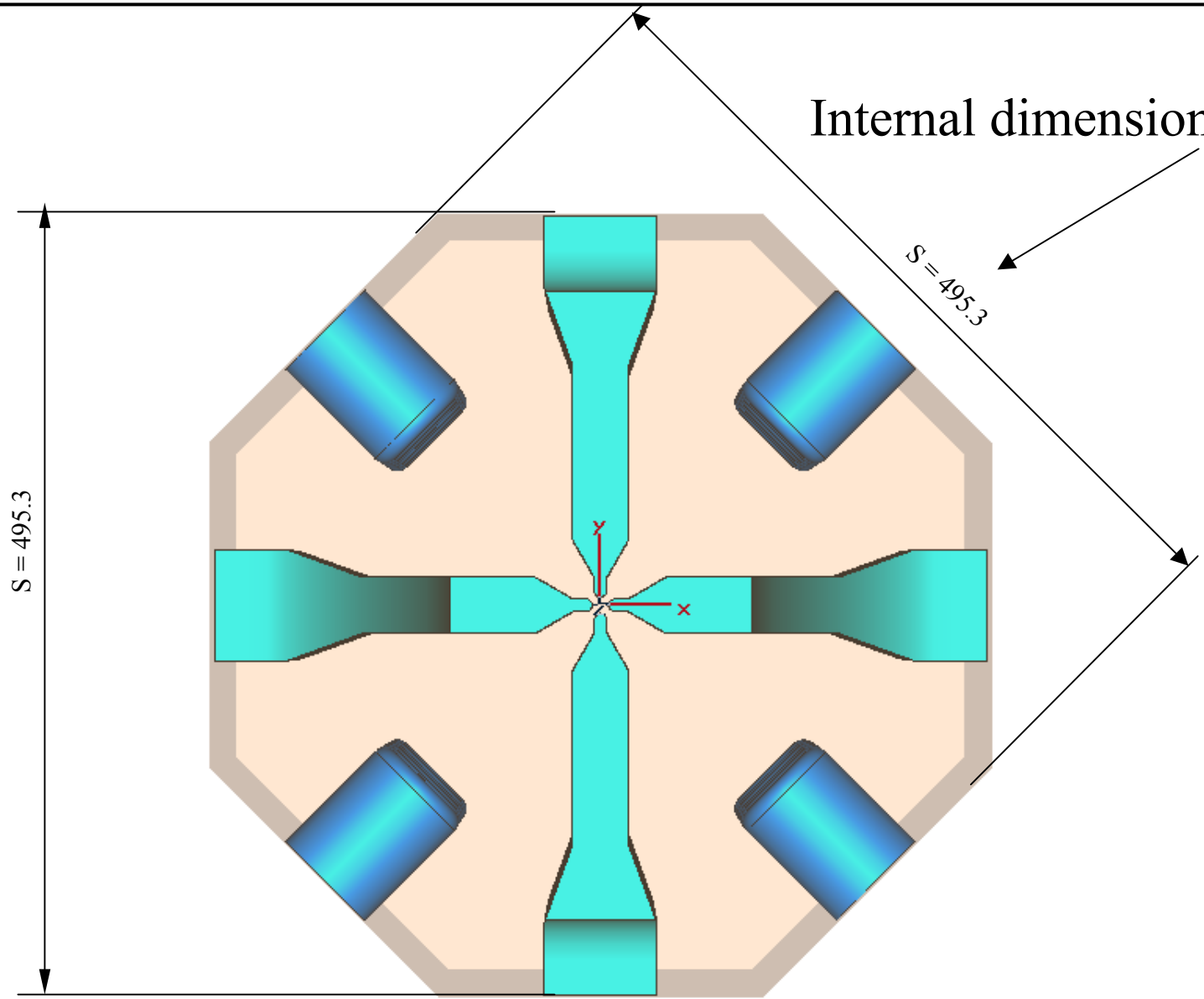
2 charge state beam at the entrance of the SRF linac



RFQ resonant structure

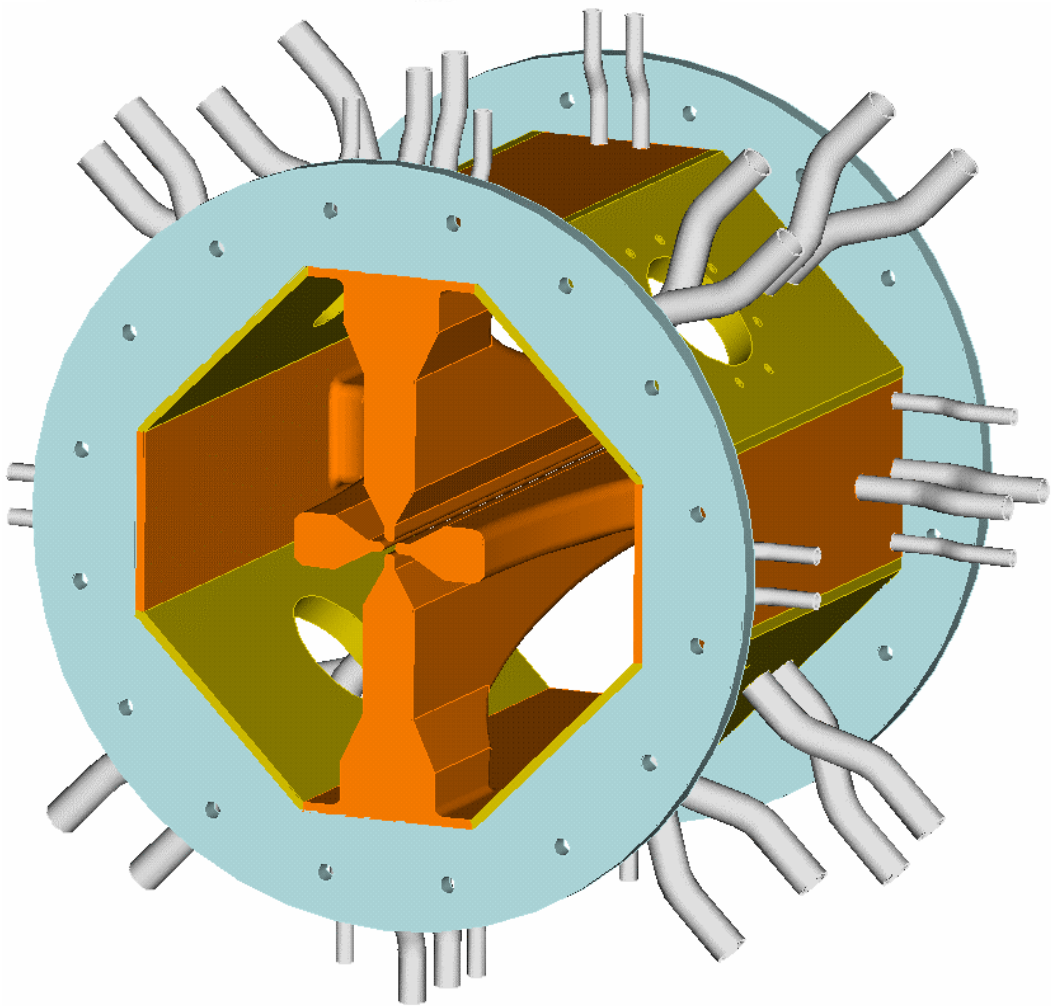


Cross Section of the Octagonal Resonator

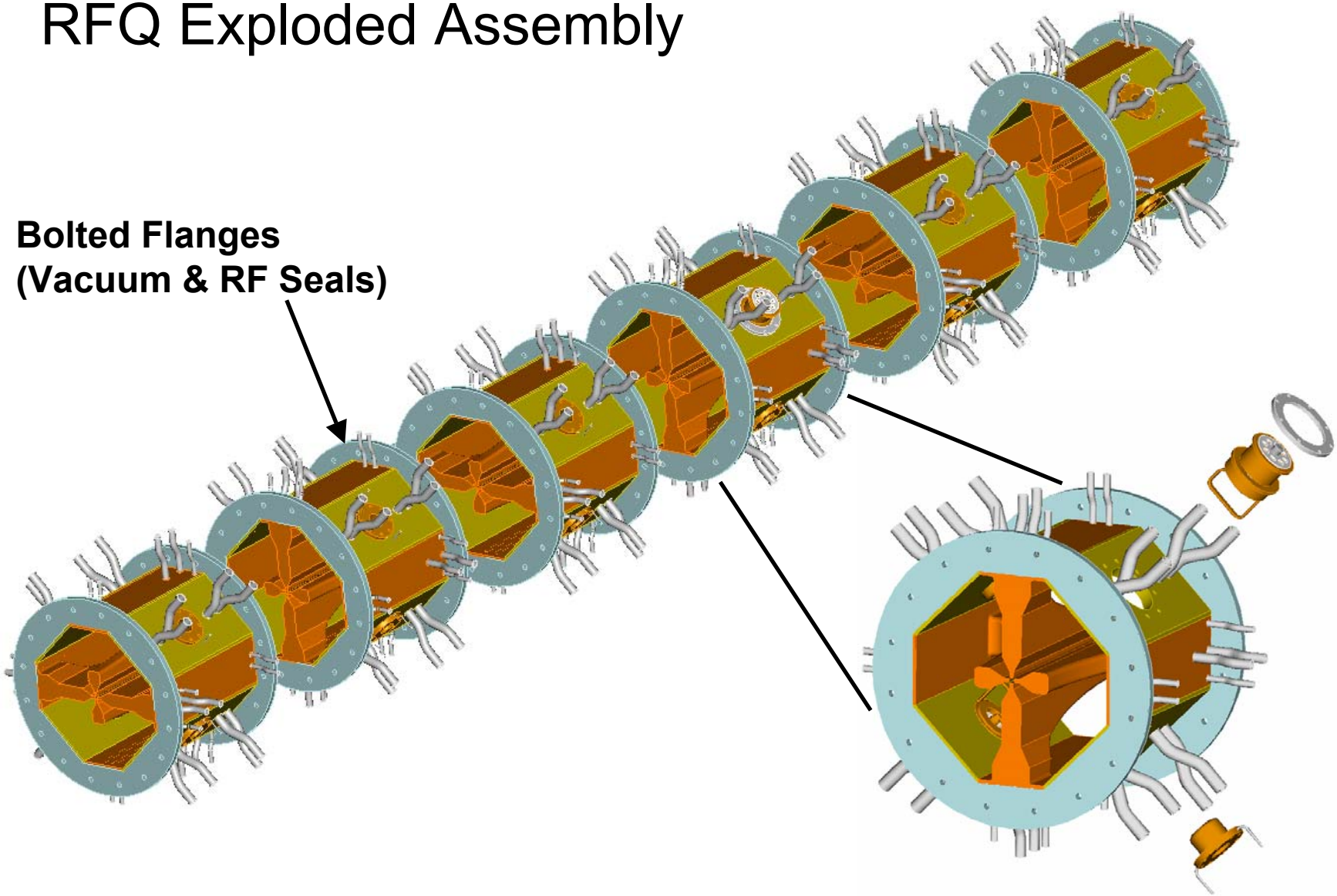


Tank Construction:
Full copper, brazed structure

Segment Final Assembly
- Approx. Weight = 1,620 lbs



RFQ Exploded Assembly



Characteristics of the pseudo split-coaxial RFQ resonator

- **Modular structure. The brazing technique which is well established for 4-vane RFQs can be applied. Brazing provides the best electrical properties of rf structures;**
- **Small transverse dimensions for low frequencies;**
- **Large frequency separation of non-operating modes;**
- **Uniform field distribution along the z-axis;**
- **High shunt impedance (45 kW for 4 meter structure);**
- **Symmetric design guarantees low field perturbations due to possible thermal distortion, no dipole component of the fields in the aperture;**
- **Provides good mechanical stability of the construction together with precise alignment ability.**
- **Details are in Nickolai Vinogradov's talk.**

Needs for future work

- Further optimizations and beam dynamics studies of the front end are needed:

  - Design of the HV extraction electrodes using realistic multi-q beam parameters from the ECR source.

  - Optimization of the achromatic bend with multi-q beam and space charge;

  - Study of alternative options of the LEBT;

  - Optimization of the injector systems.

  - Beam collimation, cleaning of the 4-dimensional beam emittance in the LEBT and MEBT.

  - Design of the light-ion injector based on an additional RFQ to provide high reliability of the driver linac.

- Build prototype of the 2q -LEBT including ECR, achromatic bends, MHB and one-segment RFQ. Main goals are:

  - Confirm two-charge-state low-emittance performance of the LEBT and RFQ.

  - Test of gridless multi-harmonic buncher, high frequency $\lambda/4$-type.

  - RFQ test. a) Fabrication technique; b) Operation in wide dynamic range of rf power without multipacting.